Smith, G. M. 1944. Marine algae of the Monterey Peninsula. vii + [1] + 622 pp., incl. 98 pls.
Sonder, O. G. 1845. Nova algarum genera et species, quas in itinere ad oras occidentales Novae Hollandiae, collegit L. Preiss, Ph.Dr. Bot. Zeit. 3: 49–57.
Stackhouse, J. 1809. Tentamen marino-cryptogamicum, . . . Mem. Soc. Imp. Nat. Moscou, 2: 50–97.
———. 1816. Nereis britannica, ed. 2. xii + 68 pp., 20 pls. Oxford.
Tandy, G. 1935. Additions and amendments to the international rules of botanical nomenclature, ed. 3. Appendix III. 1. Algae. Kew Bull. 1935: 82–83.
Taylor, W. R. 1939. Algae collected by the "Hassler," "Albatross," and Schmitt Expeditions. II. Marine algae from Uruguay, Argentina, the Falkland Islands, and the Strait of Magellan. Papers Michigan Acad. Sci., Arts and Letters 24: 127–164, 7 pls.

GERMINATION OF PHACELIA SEEDS

Clarence R. Quick

In the fall of 1942 the writer made some tests on the germinative reactions of *Phacelia* seeds. This work was carried on to facilitate cyto-taxonomic studies in *Phacelia* being carried on by Dr. Marion S. Cave and Dr. Lincoln Constance of the Department of Botany, University of California, Berkeley, which have culminated in the publication of three papers on chromosome numbers in the Hydrophyllaceae (Univ. Calif. Publ. Bot. 18: 205–216. 1942; 18: 293–298. 1944; in press). The methods used were based upon previous experience in the germination of seeds of *Ribes* and *Ceanothus,* and of other plants native to California. *Ribes* seeds, which are similar to those of *Phacelia* in size, appearance, and ecologic relationships, have been studied extensively by the writer during the past fifteen years.

Quick (1935) showed that germinative reactions of *Ceanothus* species vary widely, and that variations tend to correlate with the ecologic and taxonomic affinities of species and groups of species concerned. Mirov (1936) summarized the results of a large number of germination tests on seeds of native California plants with respect to taxonomic position, altitudinal distribution, and growth form of the species concerned. In general he found no consistent relation between systematic position and germinative behavior, but he did find definite correlations between germinative behavior and altitudinal distribution. He found that failure of germination due to seed-coat dormancy was more common in plants from low altitudes, and that failure due to embryo dormancy was more often encountered in plants from high altitudes. Seeds of annuals were less generally dormant than seeds of herbaceous perennials, shrubs, and trees.

The low germination percentages for some samples of *Phacelia* seeds, as reported by Mirov (1940) and Mirov and Kraebel (1937), suggested that stratification might be necessary to satis-

TABLE 1.

Germination of *Phacelia* seeds in the greenhouse after stratification for periods and at temperatures indicated. (Figures are percentages of seedlings that emerged from sand culture.)

Plant species*	Approximate altitude at which plant was collected (feet)	Germination after first stratification				Additional germination after second stratification				Additional germination after third stratification	
		Flat A No stratification (control)	Flat B 5° C., 86 days	Flat C 2.2° C., 114 days	Flat D 0° C., 142 days	Flat A 2.2° C., 112 days	Flat B 2.2° C., 112 days	Flat C 0° C., 140 days	Flat D 0° C., 154 days	Flat A 0° C., 154 days	Flat B 0° C., 147 days
P. distans Benth.	6,000	**26**†	16	8	2	2	0	4	13	2	6
P. vallicola Congdon	5,600	**93**	**76**	37	13	0	0	7	0	0	0
P. Quickii J. T. Howell	6,100	**85**	**44**	25	33	**3**	1	3	0	0	0
P. distans Benth.	5,000	**60**	**67**	**47**	27	7	**7**	20	0	**7**	**7**
P. Lemmonii A. Gray	3,000?	**62**	**62**	**96**	**47**	**20**	0	0	0	**1**	0
P. mutabilis Greene	6,500	0	6	**65**	**67**	54	15	**17**	2	**16**	35
P. leucophylla Torr.	8,000	2	0	**42**	**80**	38	28	**32**	0	20	**52**
P. dasyphylla Greene	11,000	0	0	**25**	0	6	0	**69**	19	44	50
P. alpina Rydb.	7,500	0	0	24	**84**	10	30	**46**	**12**	34	**52**
P. mutabilis Greene	8,500?	0	0	13	**60**	50	3	**83**	**33**	**50**	27
P. mutabilis Greene	6,500	0	6	10	**54**	**70**	21	37	**18**	**18**	**63**
P. compacta Greene	8,400	0	2	2	**58**	3	8	**75**	**18**	48	**63**
P. alpina Rydb.	11,100	0	0	14	**43**	29	43	43	0	29	**57**
P. compacta Greene	10,200	0	0	8	**44**	20	30	58	12	32	12
P. mutabilis Greene	6,300	0	4	18	**24**	22	32	36	22	42	**38**
P. leucophylla Torr.	Unknown	0	0	0	**38**	0	0	69	5	64	31

* First 5 species of *Phacelia* are annuals; the last 11 are, according to Lincoln Constance, members of the *P. magellanica–californica–heterophylla* polyploid complex.

† Figures in bold face type represent the highest percentage for each collection and all germinations of 40 per cent or more following the first stratification, or of totals of 70 per cent following the second and third periods.

factory germination of many species of *Phacelia* seeds. Unpublished data of the author indicated that seeds of *Phacelia mutabilis* had dormant embryos, and suggested also that the seed coat was somewhat impermeable to water. Quick (1943) outlined several common methods of forcing germination of dormant seeds. Dormant seeds, that is, seeds not immediately germinable, often grow satisfactorily in the greenhouse if the germination period is immediately preceded by one of stratification, that is, by a period of refrigeration with an adequate supply of air, moisture, and mineral nutrients. Difficulty in plumping seeds with slightly impermeable seed coats is sometimes obviated by repeated alternate exposures at stratification and greenhouse temperatures. Another treatment which is sometimes successful with hard-coated seeds, and which may be called delayed stratification, subjects dormant seeds to greenhouse temperatures under favorable germinative conditions prior to any refrigeration treatment. This delayed stratification treatment is attained if a control culture—a culture placed in the greenhouse immediately after planting to see whether untreated seeds will germinate—is subjected to treatment in cold storage, following the exposure at the greenhouse temperature, and is then retested for germination.

Table 1 presents results of germination tests upon seeds of several species of *Phacelia* listed in the approximate order of their germinative reactions. The sequence of treatments applied to flat A may be outlined as follows: The seeds were planted in moist, washed, autoclaved river sand on October 11, 1942. The cultures were wet with a mineral nutrient solution and thereafter kept moist at all times, treated with copper oxalate to prevent damping-off, and placed immediately in the greenhouse for germination test. After 56 days in the greenhouse they were subjected to 112 days of stratification at 2.2° C. and were then returned to the greenhouse. After a second germination period of 35 days they were again placed in stratification, this time at 0° C. for 154 days. On October 5, 1943, they were placed in the greenhouse for a third germination test and after 35 days were discarded. Flats B, C, and D were given a similar sequence of treatments. The tests averaged about 50 seeds per culture.

From the author's experience with many seeds, especially with those of *Ribes,* the maximum effects from stratification can be expected from the three low temperatures of 5°, 2.2°, and 0° C., for periods of approximately 84, 112, and 140 days, respectively.

It is apparent that seeds of the four annual species of *Phacelia* were not dormant; that is, there was little or no interference to immediate greenhouse germination. Seeds of these species were usually collected at lower altitudes than the perennial species. Seeds of many of the perennial species were best conditioned for germination by stratification at 0° C. In germination tests follow-

ing the first refrigeration treatment, one sample showed germination only after stratification at 0°. Several species failed to germinate after stratification at 5°. Stratification at 0° may obviate seed-coat dormancy more effectively than stratification at slightly higher temperatures because of the probable alternation of temperatures above and below the freezing point of water. In any event, stratification at 0° was generally much more satisfactory for conditioning seed of the perennial species for germination. This result suggests that some of the special treatments for making hard seeds permeable to water might be used to advantage on a number of *Phacelia* species. The appreciable germination obtained after second and even after third refrigeration indicates that freezing-point stratification may be used advantageously on many *Phacelia* species, and suggests again that the coats of many *Phacelia* seeds are more or less impermeable.

Under the conditions of the experiment, retrial (second) stratification at 0° C. caused many more samples to reach or exceed 70 per cent germination than retrial stratification at 2.2°. For example, in flat B retrial stratification at 2.2° after primary stratification at 5° caused only one sample to reach 70 per cent germination, whereas still another (third) stratification of the same flat, at 0°, caused seven additional samples to equal or exceed 70 per cent germination.

In conclusion, then, it appears that seeds of many annual species of *Phacelia* will grow immediately and without special treatments designed to obviate seed dormancy. Seeds of many perennial species are satisfactorily conditioned for germination by stratification treatment at 0° C. for 140 days. An alternation of stratification periods at low temperature with germination periods in the greenhouse is more generally productive of seedlings than a single stratification treatment followed by a germination period in the greenhouse.

Bureau of Entomology and Plant Quarantine,
Agricultural Research Administration,
United States Department of Agriculture,
Berkeley, California.

Literature Cited

Mirov, N. T. 1936. Germination behavior of some California plants. Ecology 17(4): 667–672.

———. 1940. Additional data on collecting and propagating the seeds of California wild plants. U. S. Forest Serv., Calif. Forest and Range Expt. Sta., Res. Note 21, 17 pp. [Processed.]

Mirov, N. T., and C. J. Kraebel. 1937. Collecting and propagating the seeds of California wild plants. U. S. Forest Serv., Calif. Forest and Range Expt. Sta., Res. Note 18, 27 pp. [Processed.]

Quick, C. R. 1935. Notes on the germination of *Ceanothus* seeds. Madroño 3: 135–140.

———. 1943. Certain methods of forcing the germination of seeds. Jour. Calif. Hort. Soc. 4: 95–102.